A SKYLAB DEMONSTRATION PROJECT

THE UTILITY OF SKYLAB S-190A AND B FOR MEASURING WATER QUALITY PARAMETERS IN KANSAS RESERVOIRS

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FOR

SKYLAB STUDY OF WATER QUALITY

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COLOR

Original photography may be purchased from:
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INTRODUCTION

The objective of this Skylab demonstration project is to study Kansas reservoirs using Skylab S 190A & B imagery in conjunction with simultaneous ground truth information in an attempt to detect and monitor various parameters of water quality. The primary study areas; Perry and Tuttle Creek Reservoirs in northeast Kansas, were not covered by EREP passes, necessitating the selection of secondary targets in southeast Kansas. These targets are Toronto, Fall River, and Elk City Reservoirs which occur in the upper part of the Verdigris River watershed (Figure 1).

EREP data was collected over these three lakes on September 18, 1973 along track 58. Concurrent with satellite overflight, field crews were on all three lakes collecting water samples. The sampling plans for these three lakes are shown in figures 2, 3, and 4. These samples were analyzed for concentrations of bicarbonate, carbonate, calcium, magnesium, potassium, sodium, sulfate and chloride. In addition, total solids, total heat-stable solids, suspended solids, heat-stable suspended solids, and pH were determined.

EREP data products thus far received for the Sept. 18, SL3 pass over southwest Kansas include S-190A positive transparencies both 70 mm and 4 X enlargements, and S-190B positive transparencies. Film density measurements were done by a Macbeth EP-1000 densitometer. In addition, the IDECS (our Image Discrimination, Enhancement, and Combination System) was used to assist qualitative film analysis.

Visual inspection of the reservoirs contained in the S-190A & B imagery detected tonal variations between lakes but not within a particular lake. In general Toronto Reservoir appeared to have a brighter appearance than the other two lakes, however, none of the lakes displayed recognizable turbidity patterns. Analysis with IDECS using density-to-hue conversion uncovered some variations on S-190A and B photos of Elk City Reservoir. IDECS was unable to detect density variations across the surfaces of the other two lakes. Figure 5 is a color substituted S-190A, band 0.5-0.7 μ-(red) photo of Elk City Reservoir. Two regions are delineated; a lower density region in the upper part of the lake and a higher density region elsewhere. Although suspended solids measurements of the Elk City samples do not show much variations; higher concentrations are found in the lower density region.

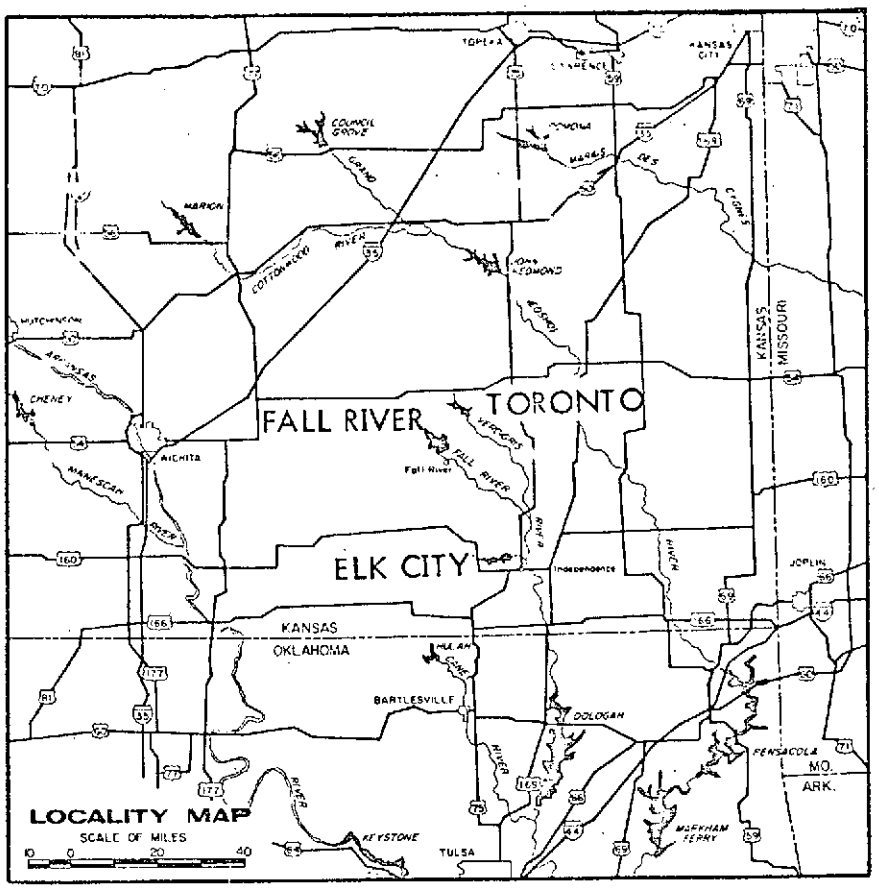

FIGURE 1. RESERVOIR LOCATION MAP.

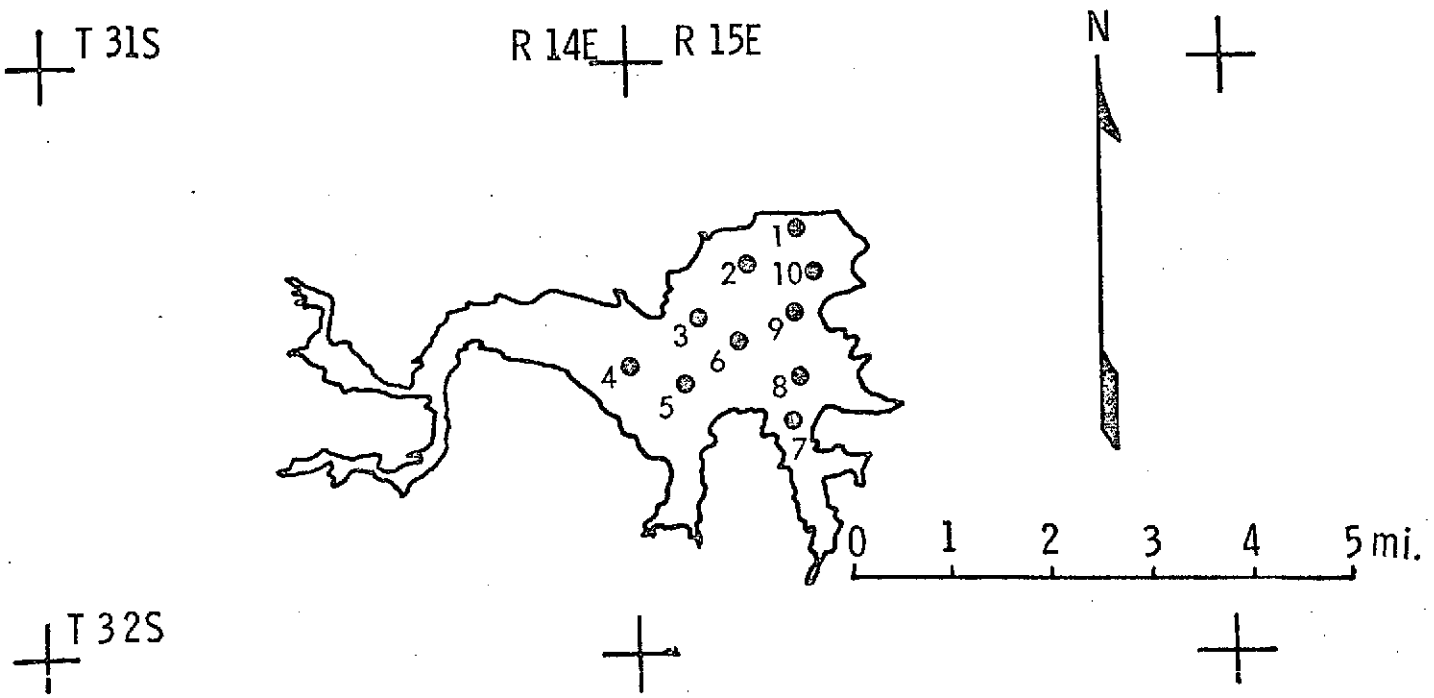

FIGURE 2. ELK CITY RESERVOIR.

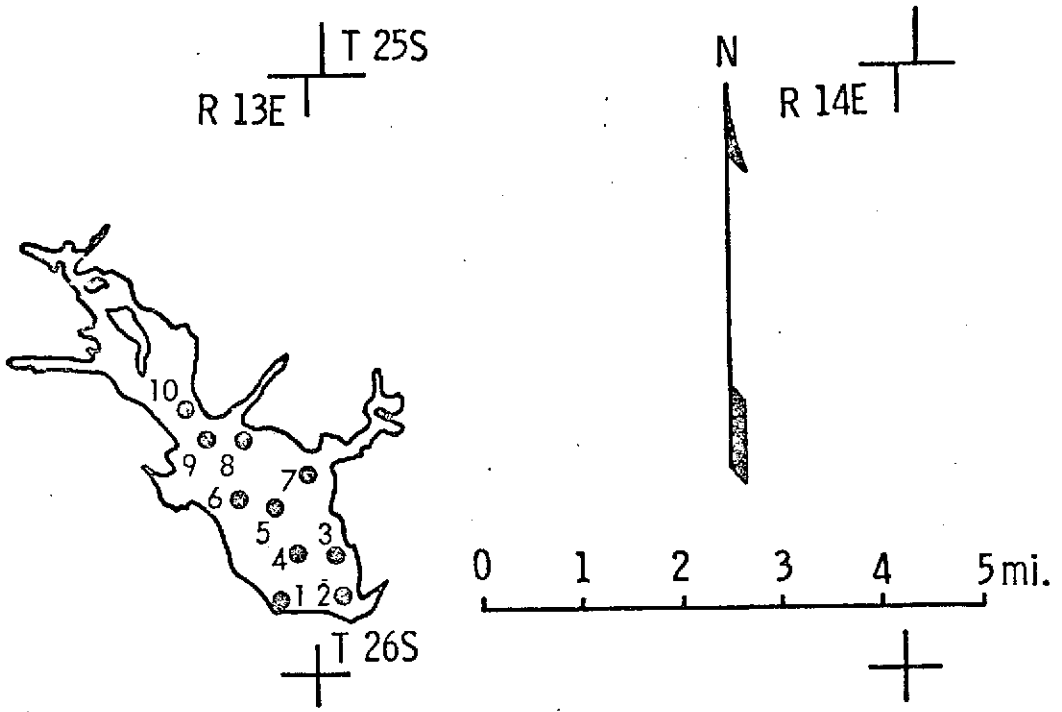

FIGURE 3. TORONTO RESERVOIR.

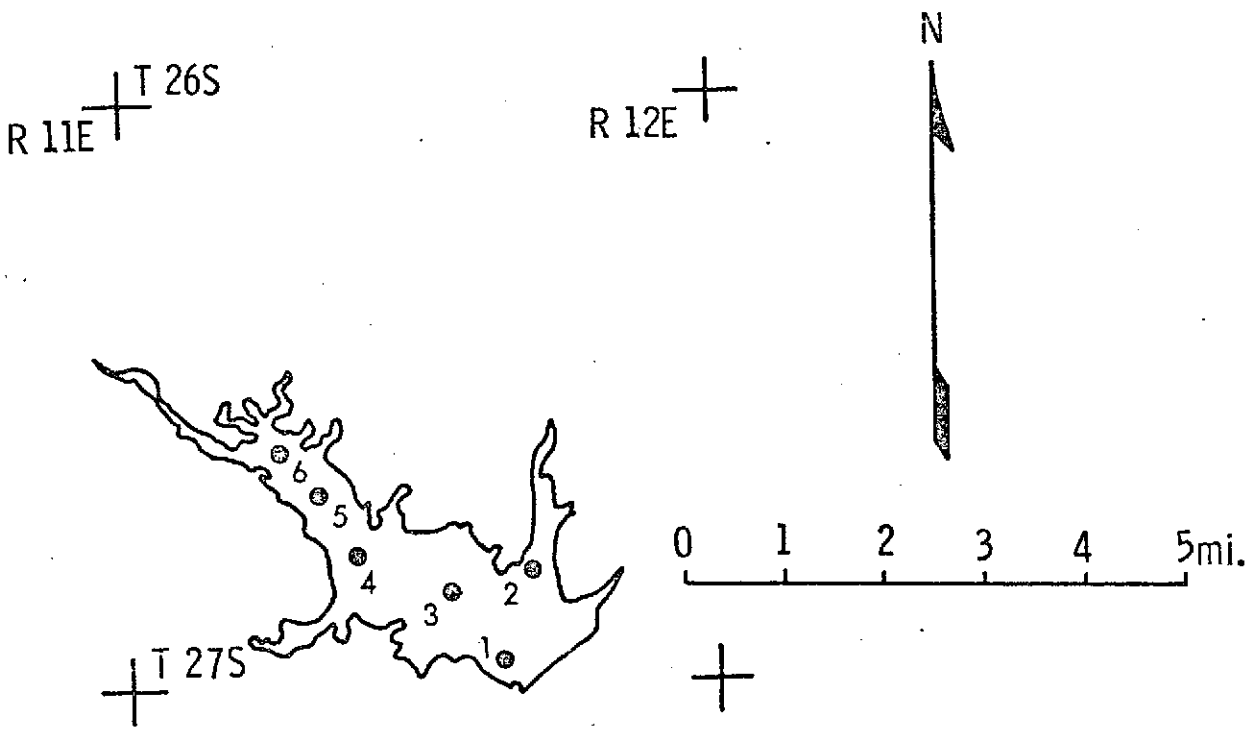

FIGURE 4. FALL RIVER RESERVOIR.

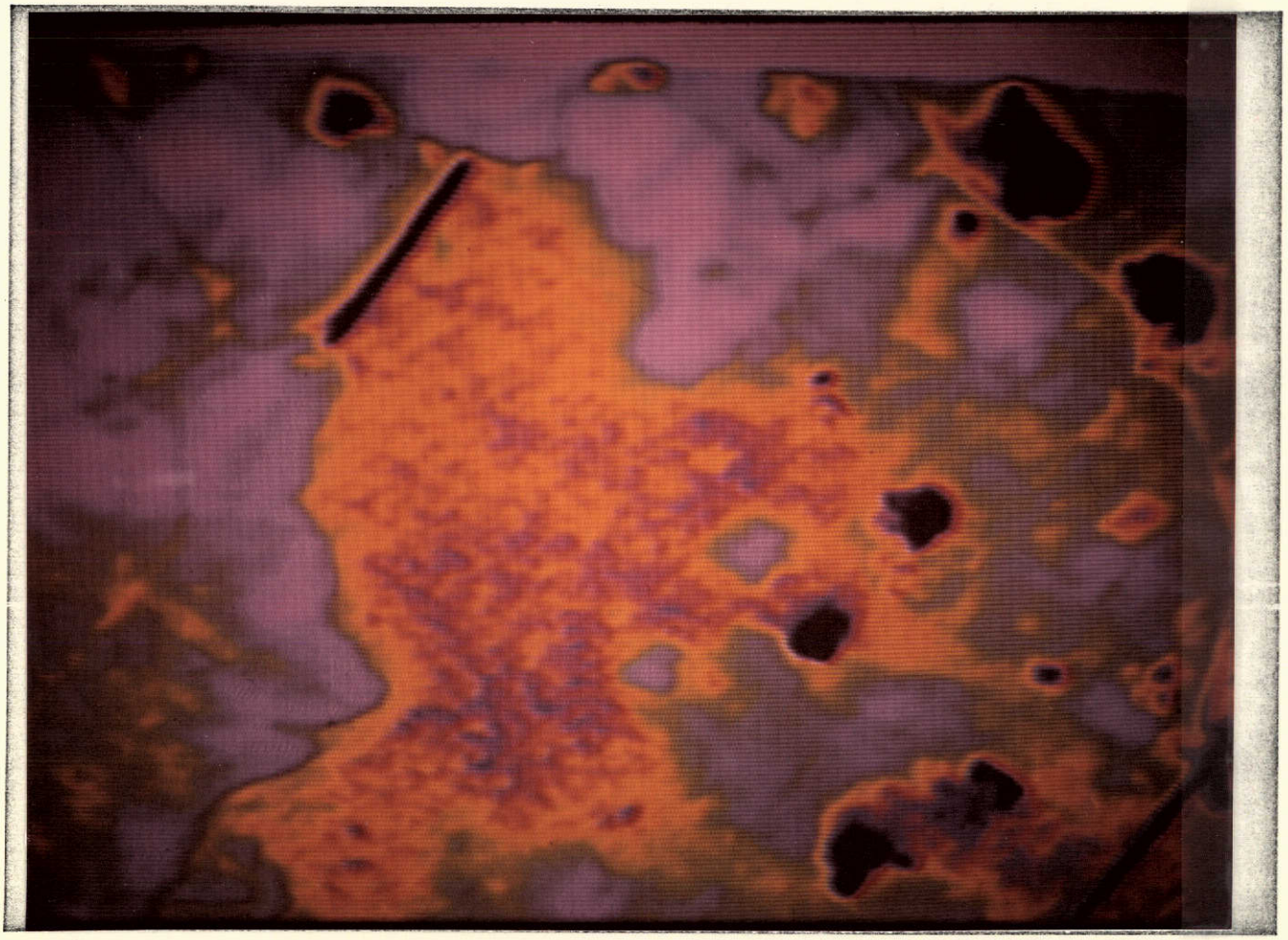

FIGURE 5. IDECS COLOR ENHANCED RED BAND S-190A PHOTO OF ELK CITY RESERVOIR.

IDECS provides only qualitative information concerning film density variation and is not as sensitive as a densitometer. The four black and white S-190A products were analyzed quantitatively with our macrodensitometer. The bands analyzed were 0.5-0.6 μ green (roll 48), 0.6-0.7 μ-red (roll 47), 0.7-0.8 μ-first infrared (roll 43), and 0.8-0.9 μ second infrared (roll 44). Measurements were made on 4 X enlarged transparencies since the lakes appeared too small on the 70 mm format for accurate measurements. The aperture size used was 1 mm.

Five locations were selected on Fall River and Toronto Reservoirs, and four from Elk City. Each density measurement was centered as nearly as possible over one or more ground truth sampling station. Attempts were then made to relate film density to corresponding water quality parameters. Previous experience in working with ERTS imageryhas shown that suspended solids dominate the appearance of Kansas reservoirs in satellite imagery in the visible and near-infrared region.

In figure 6 density is plotted against suspended solids for all three lakes and for all four bands of black and white photography. The sample stations show a range in suspended solids from about 25 ppm to nearly 90 ppm. Based on extensive sampling of Kansas Reservoirs the last 2 years, these figures represent relatively clear water. In general these lakes are well mixed, in that the suspended solids measurements of each lake fall within a small range of values. These measurements substantiate the visual and IDECS analyses of the photos which failed to detect major tonal variations within any of the lakes. Some variation in tone does exist however, and this is especially evident in the red and green bands. In general both bands show a correlation with suspended solids that decreases with increasing concentrations. The red band to some extent and particularly the green band density levels for Elk City Reservoir are unexpectedly low. Atmospheric factors maybe responsible for the lighter tones of Elk City since green light is more susceptible to scattering by atmospheric particulates. A weather front in the vicinity and pollutants from nearby oil refineries are possible causes of variation in atmospheric turbidity in this area.

The infrared film densities decrease slightly with higher amounts of suspended solids. This smaller degree of sensitivity to concentrations of suspended material would be anticipated due to the greater amount of absorption of infrared energy by water.

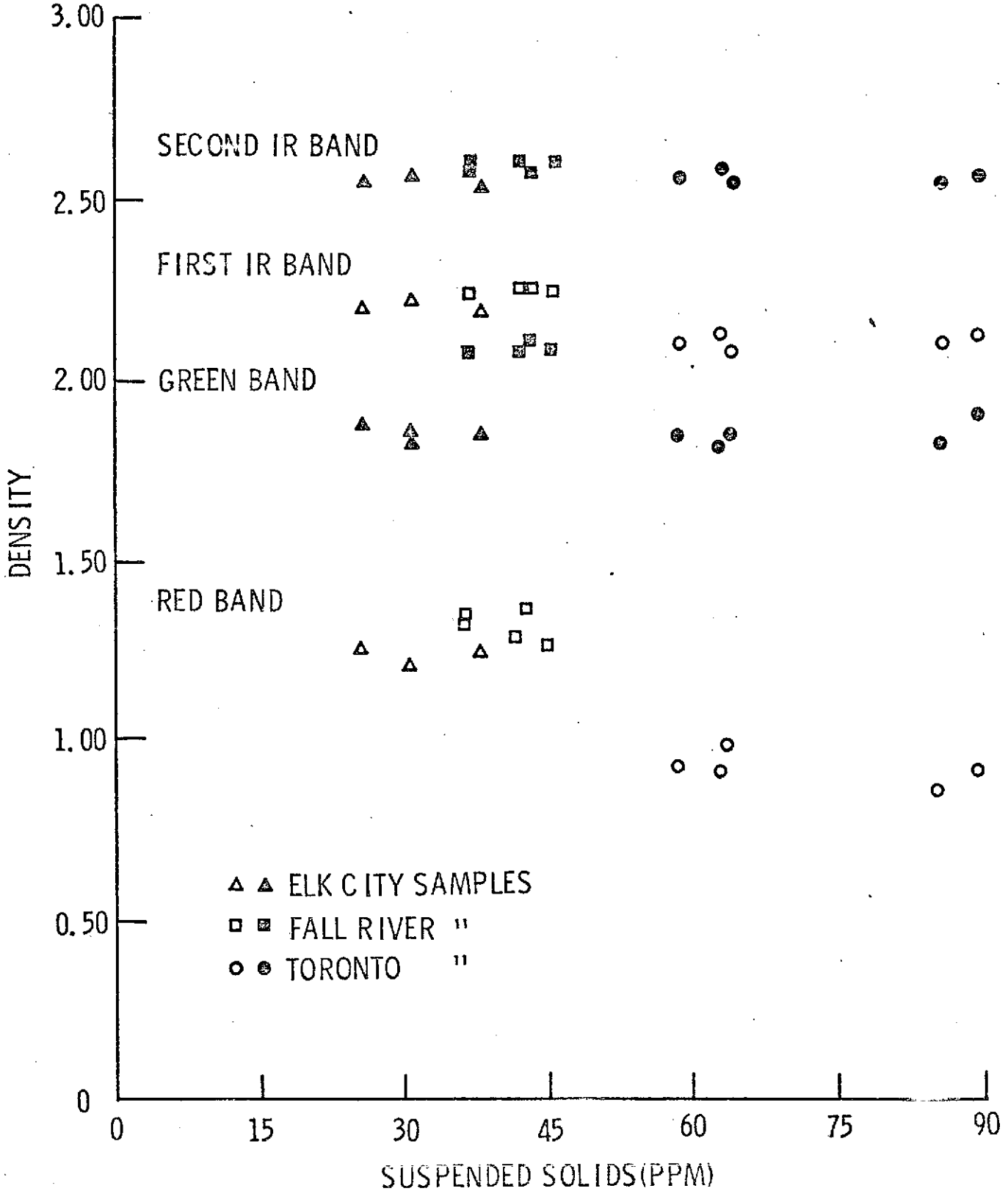

FIGURE 6. S-190A IMAGE DENSITY VS. SUSPENDED SOLIDS FOR WATER SAMPLES TAKEN FROM 3 SOUTHEAST KANSAS RESERVOIRS, SEPT. 18 1973.

Vincent (1972) has suggested band ratios as a means of suppressing sun-angle dependence and atmospheric effects. Such band ratios were used in a recently completed ERTS-1 study of water quality (Yarger and McCauley, 1974) and were quite useful in correlating data collected at different sun angles and atmospheric conditions. In an attempt to improve correlation between Skylab data and ground truth, red/green band ratios were computed and plotted against suspended solids.

Before ratioing, density measurements were converted to values proportional to radiance detected by the S-190A sensor. If the reservoir densities are in the linear region of the density vs. log (exposure) curve for the film, then the ratio can be written as

$$\frac{Ei}{Ej} = k \frac{10^{-Di}}{10^{-Dj}}$$

where Ei and Ej are band i and j radiances from the target and Di and Dj are corresponding film densities. K is a constant determined by the slope of the D vs. log E curve which relates the density of our film copy to the original exposure on Skylab. K also depends on filter and camera face attentuation coefficients. This constant has not yet been determined but is inmaterial in establishing correlation between imagery and sample analysis. The red to green band ratio is shown in figure 7 and exhibits a good linear dependence on suspended solids with RMS residual of 6 ppm. A similar plot is shown in figure 8 in which comparable ERTS-1 data is plotted. MSS 5(Red) over MSS 4 (Green) is equivalent to the red to green S-190A ratios. Figure 8 represents substantially more data collected during a year of ERTS imaging under varying conditions of illumination and sky conditions and over a wide range of suspended solids concentration. The Skylab data (Figure 7) compares favorably to the ERTS data (figure 8) in the region 0-80 ppm. Beyond 80ppm the ERTS MSS red/green ratio flatten out. We would expect the Skylab S 190A red/green ratio to also flatten out, but the relatively clear water sampled does not permit confirmation of this. The highest two points in figure 7 do, perhaps, indicate a similar flattening.

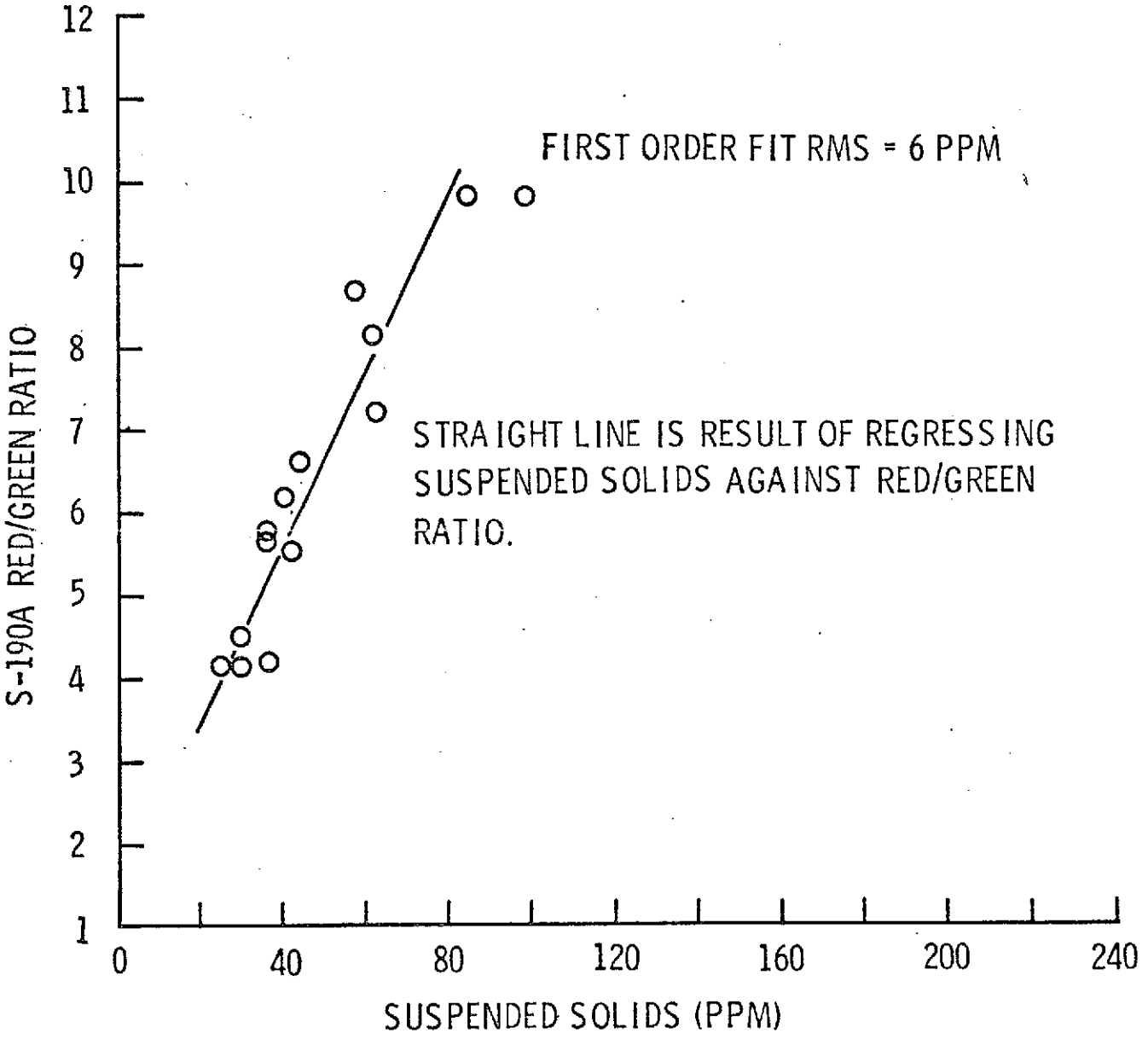

FIGURE 7. RED/GREEN RADIANCE RATIOS VS. SUSPENDED SOLIDS FOR WATER SAMPLES TAKEN FROM 3 SOUTHEAST KANSAS RESERVOIRS, SEPT. 18 1973 (RED/GREEN RATIO IS DEFINED IN TEXT).

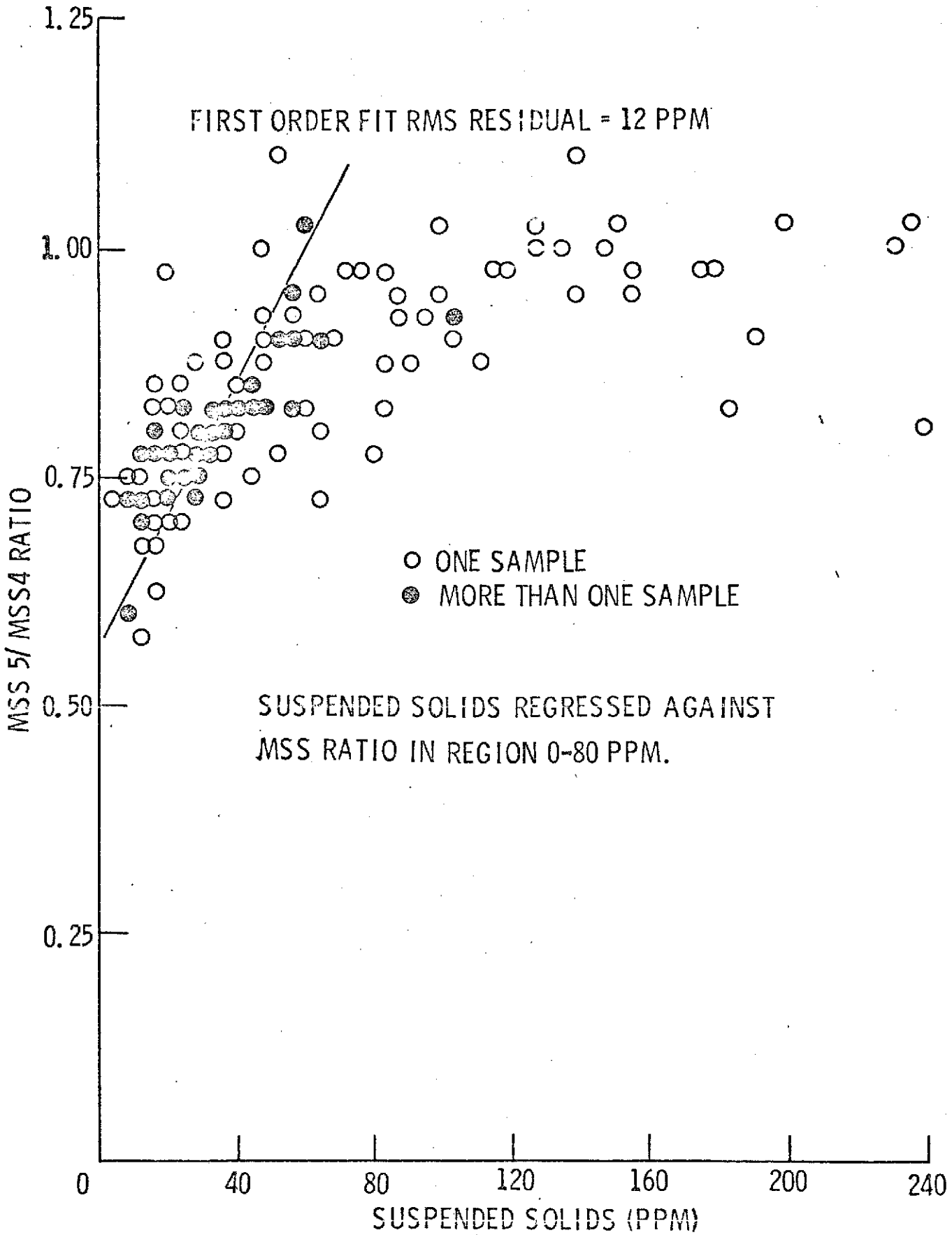

FIGURE 8. MSS 5/MSS 4 CCT RATIO VS. SUSPENDED SOLIDS FOR 167 WATER SAMPLES TAKEN FROM 3 KANSAS RESERVOIRS DURING 13 DIFFERENT ERTS-1 CYCLES.

CONCLUSIONS

Analysis of S-190A imagery from 1 EREP pass over 3 reservoirs in Kansas establishes a strong linear correlation between the red/green radiance ratio and suspended solids. This result compares quite favorably to ERTS MSS CCT results. The linear fit RMS for Skylab is 6 ppm as compared to 12 ppm for ERTS. All of the ERTS satellite passes yielded fairly linear results with typical RMS values of 12 ppm. However, a few of the individual passes did yield RMS values of 5 or 6 ppm which is comparable to the one Skylab pass we were able to analyze. In view of the cloudy conditions in the Skylab photo, yet good results, the indications are that S-190A may do somewhat better than the ERTS MSS in determining suspended load. More S-190A data is needed to confirm this. As was the case with the ERTS MSS, the Skylab S-190A showed no strong correlation with other water quality parameters.

S-190A photos because of their high resolution can provide much first look information regarding relative degrees of turbidity within various parts of large lakes and among much smaller bodies of water.

REFERENCES

Vincent, Robert K., (1972), "An ERTS Multispectral Scanner Experiment for Mapping Iron Compounds": Proceedings of the Eighth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, Oct. 2-6, pp. 1239-1243.

Yarger, H. L., J. R. McCauley, (1974), Kansas Environmental and Resource Study: A Great Plains Model; Monitoring Fresh Water Resources, Final Report. NASA Contract No. NAS 5-21822 Task 5.